LEAF ANATOMY MONOGRAPH

Photomicrographs of Leaf Transections of Twenty-Nine Plant Genera

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by

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INTRODUCTION

In studies on the interaction of electromagnetic radiation with plant leaves, many transections (cross-sections) of leaves were processed histologically and photographed through a microscope. These photomicrographs are presented here, with added abbreviations to identify gross cellular structures or tissues making up the leaf anatomies of 29 plant genera.

The authors gratefully acknowledge assistance from:

Dr. Craig L. Wiegand - suggestions for preparing and writing the report.

Dr. Lazern O. Sorensen, Pan American College, Edinburg, Texas - help in identifying cells for *Agave americana* L., *Opuntia* spp., *Philodendron selloum* C. Koch (P. Sellowi, Hort.), and *Hibiscus* spp.

Jean Ryan - typing and collating the report.

Guadalupe Cardona - art work.

PLANTS SAMPLED

Fully-grown true leaves were sampled from the plants below. Appendages of *Agave americana* L., *Opuntia* spp., and *Ulva* spp. that function as leaves have been included. These were not necessarily fully grown.

Latin names given are from Bailey (1928) and Fernald (1950). Common names (the first where there are more than one) are used to identify the photomicrographs.

Common (colloquial) name(s)	Latin name	Figure
Alfalfa	*Medicago sativa* L.	1
Avocado	*Persea americana* Mill.	2
Apple	*Malus sylvestris* Mill.	3
Bean (lima)	*Phaseolus limensis* Macfad.	4
Bermuda grass, scutch grass	*Cynodon dactylon* (L.) Pers.	5
Bougainvillea	*Bougainvillea spectabilis* Willd.	6
Cantaloupe	*Cucumbis melo* L.	7
Century plant, Maguey	*Agave americana* L.	8
Corn, maize, Indian corn	*Zea mays* L.	9
Cotton	*Gossypium hirsutum* L.	10
Croton	*Codiaeum variegatum* Blume	11
Flax	*Linum usitatissimum* L.	12

Common (colloquial) name(s)	Latin name	Figure
Grapefruit	*Citrus paradisi* Macf.	13
Hibiscus	*Hibiscus* spp.	14
Marine morning-glory	*Ipomea stolonifera* (Cyril) Poir	15
Oleander	*Nerium oleander* L.	16
Orange	*Citrus aurantium* L.	17
Philodendron, split-leaf philodendron, split-leaf Monstera	*Philodendron selloum* C. Koch (*P. Sellowi*, Hort.)	18
Prickly pear, Englemann's pear	*Opuntia* spp.	19
Rice paper plant	*Tetrapanax papyriferum* Koch	20
Sea lettuce	*Ulva* spp.	21
Sea ox-eye daisy	*Borrichia frutescens* (L.) DC.	22
Sea purslane	*Trianthema portulacastrum* L.	23
Sorghum, broomcorn	*Sorghum vulgare* Pers.	24
Soybean	*Glycine max* (L.) Merr.	25
Spinach	*Spinacia oleracea* L.	26
Squash	*Cucurbita pepo* L.	27
Sweet clover	*Melilotus alba* Desr.	28
Wheat	*Triticum vulgare* Vill.	29

ABBREVIATIONS

The abbreviations below are used to identify tissues on the photomicrographs of the leaf transections. Definitions of the terms are given in the following GLOSSARY.

Abbreviations	Terms
AC	Air cavity (intercellular space)
B	Bulliform cell
BS	Bundle sheath
C	Cuticle
CH	Chloroplast
CHLO	Chlorenchyma cell
CO	Calcium oxalate crystal
E	Epidermal cell
G	Groove
H	Hair
HYP	Hypodermis
L	Lysigenous space
LT	Laticifer tube
M	Mesophyll cell
N	Nucleus
P	Palisade parenchyma cell

Abbreviations	Terms
S	Stoma
SC	Storage area or cells
SCL	Sclerenchyma cell
SCLD	Sclereid
SP	Spongy parenchyma cell
T	Trichome
V	Vein (vascular bundles, including xylem and phloem)

GLOSSARY

Sources of literature by Esau (1964 and 1965), Fahn (1967), Lee and Heimsch (1962), and Popham (1966) were used for the definitions below.

Abaxial	Leaf surface faces away from stem, or dorsal (lower) side.
Adaxial	Leaf surface faces toward stem, or ventral (upper) side.
Air cavity	Space between cells.
Bifacial leaf or dorsiventral leaf	Leaf having distinct upper and lower surfaces - palisade tissue occurs on one side of the blade, and the spongy tissue on the other.
Bulliform cell	Enlarged epidermal cell occurring in longitudinal rows of similar cells in leaves of grasses. It functions in the rolling and unrolling of leaves.

Bundle sheath	Layer or layers of cells surrounding vascular bundle; may consist of parenchyma or sclerenchyma tissue.
Centric leaf	Having continuous mesophyll from dorsal to ventral surface.
Chloroplast	Specialized protoplasmic body containing chlorophyll.
Collenchyma	The supporting tissue of young organs; cell walls are usually unequally thickened.
Cuticle	For this report it is considered as a waxy material (cutin), on or within the outer epidermal cell wall.
Cutin	A wax-like, highly complex fatty substance present within epidermal walls or as a separate layer on the outer surface of the epidermis.
Dorsal	Lower side of the leaf.

Dorsiventral leaf (See bifacial leaf)	A leaf having palisade parenchyma on one side and spongy parenchyma on the other side of the blade.
Epidermis	The outer layer of cells on both the dorsal and ventral side of a leaf.
Gamete	A sex cell; an egg or sperm.
Groove	Stomatal crypt or epidermal depression found on the dorsal surface.
Hypodermis	Layer or layers of cells beneath the epidermis sometimes used for water storage.
Isobilateral or isolateral leaf	A leaf having palisade cells on both sides of the blade.
Laticifer tubes	Tubular structures in leaves containing latex.
Lysigenous spaces	An intercellular space that originated by dissolution of cells.

Mesophyll cell	A cell located between the epidermal layers of a leaf. If cell contains chloroplasts it is a chlorenchyma cell.
Multiserrate epidermis	Multiple layer of epidermal cells.
Nucleus	A body within a cell controlling synthetic and regulatory activities, and also housing the hereditary units.
Palisade layer	A layer of elongated cells containing many chloroplasts.
Paradermal	Refers to section made parallel with the surface of a leaf.
Parenchyma	Thin-walled cells capable of growth and division; found in leaves between the lower and upper epidermis.
Phloem	Principal food-conducting tissue of the vascular plants.
Pubescent	Covered with hairs.

Sclereid	A cell with extremely thick cell walls and a crystalline appearance.
Sclerenchyma	Thick-walled cells whose principal function is strengthening (elements) of mature plant parts.
Silica cell	Cell with silica within the cell wall.
Spongy parenchyma	Mesophyll parenchyma with noticeable air cavities.
Stoma	An opening in the epidermis with two guard cells surrounding it where gas exchange takes place between the plant and air.
Stomatal crypt	Stoma that are restricted to the epidermis that lines the depressions in the leaf.
Storage cells	Large thin-walled cells used for storage.
Sunken stomata	Stomata which have sunk below the surface of the epidermis. They may appear suspended from cells arching over them.

Thallus	A plant body lacking roots, stems, and leaves.
Transection	See transverse.
Transverse	A cross section. Section taken perpendicular to the longitudinal axis of the cell. Also called transection.
Trichome	A hair-like outgrowth of the epidermis.
Unifacial leaf (See isobilateral)	A leaf having similar structure on both sides.
Vascular bundle	Vascular tissue containing xylem and phloem.
Vein	Strand of vascular material (in a leaf) containing xylem and phloem.
Ventral	Upper side of the leaf.
Xylem	Principal water-conducting tissue in vascular plants.

EXPERIMENTAL METHODS

Leaf Sampling. Fully-grown, true leaves, appendages of cacti, and the thalli of sea lettuce were sampled randomly, and their surfaces were cleaned by wiping with water-dampened tissue when necessary.

Histological Techniques. Pieces of tissue taken near the center of leaves approximately 1 cm (1/2 in) on either side of the midrib were fixed in formalin-acetic acid-ethyl alcohol, with the exception of cotton leaf tissue (Fig. 10) that was fixed in Navashin's solution (Jensen, 1962). Tissues were dehydrated with a graded tertiary butyl alcohol series, infiltrated and embedded with paraffin (melting point about 52°C), and stained with safranin-fast green. Transverse sections (transections) were made with a rotary microtome.

Microphotography. Photomicrographs were made with a Zeiss Standard Universal Photomicroscope. Enlargements of photomicrographs presented represent transections having a thickness of 12 μ and 14 μ. Magnifications are indicated on the photomicrographs.

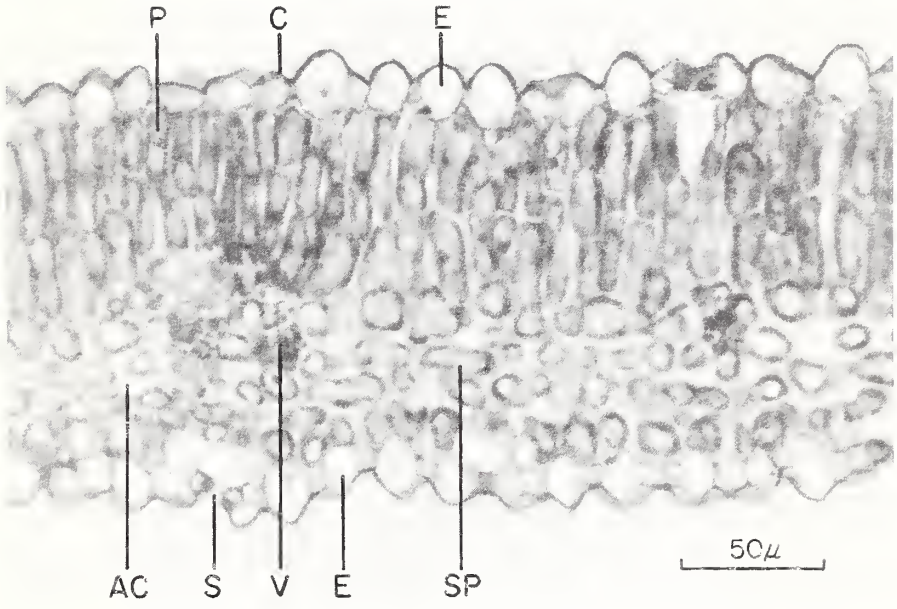

Fig. 1. Alfalfa. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layers and many intercellular spaces.

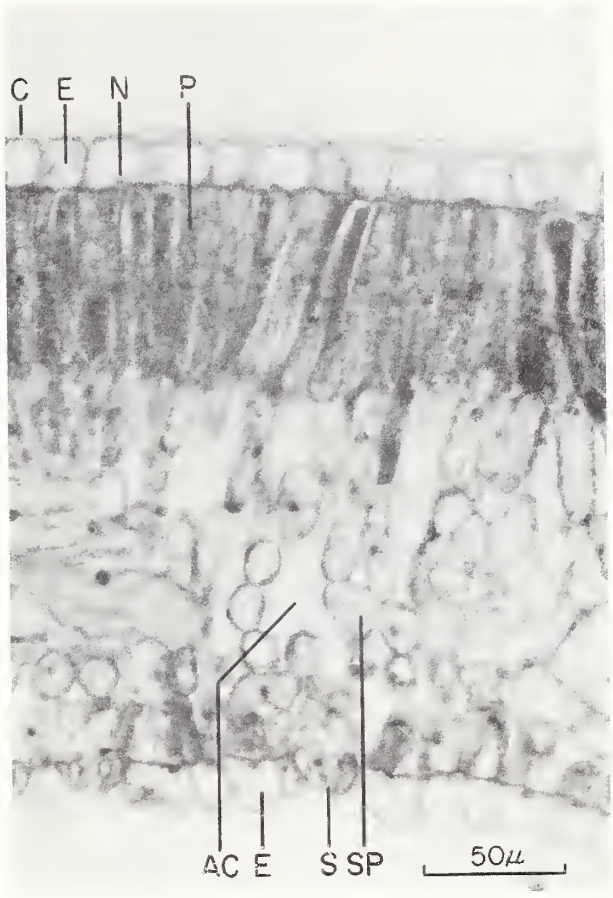

Fig. 2. Avocado. Photomicrograph of dorsiventral leaf transection. Note prominent cuticle and sclerenchyma cells (thick-walled cells in lower center of photo).

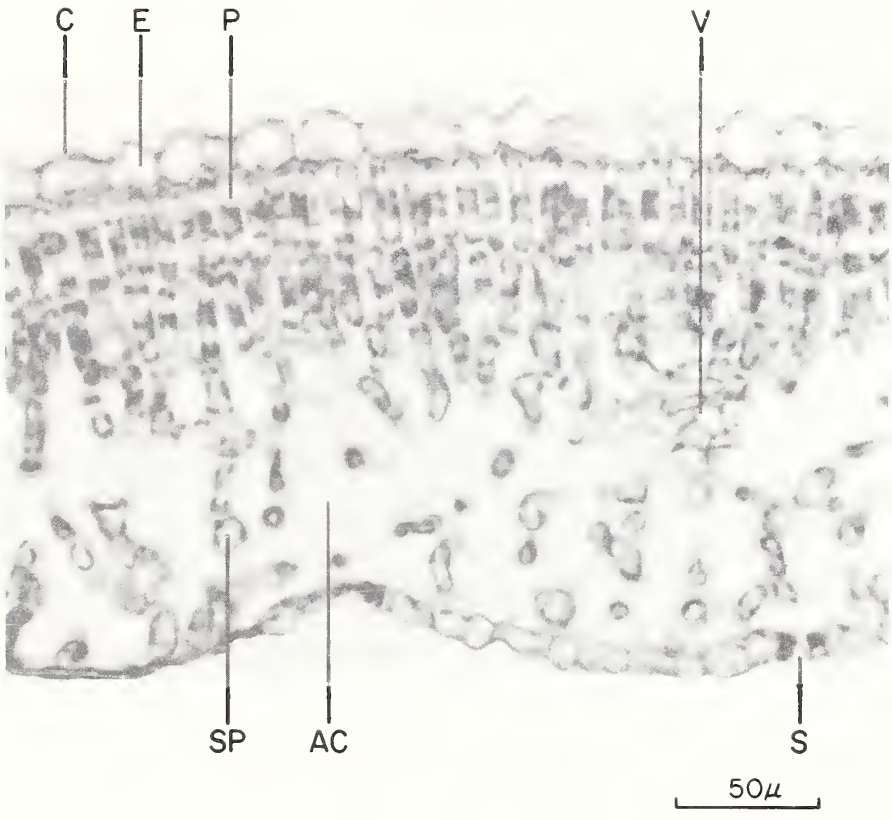

Fig. 3. Apple. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer, and large air cavities in spongy parenchyma.

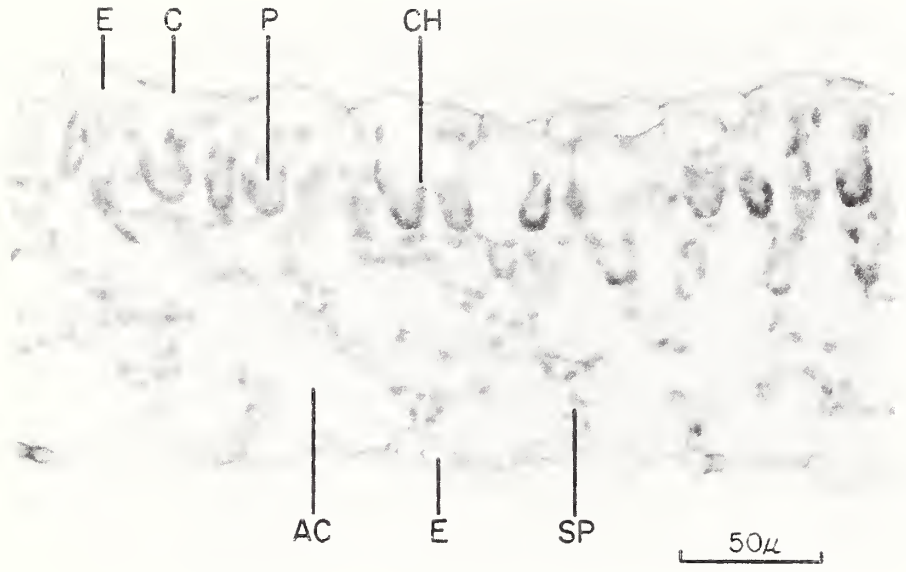

Fig. 4. Bean. Photomicrograph of dorsiventral leaf transection. Note the large amount of air space.

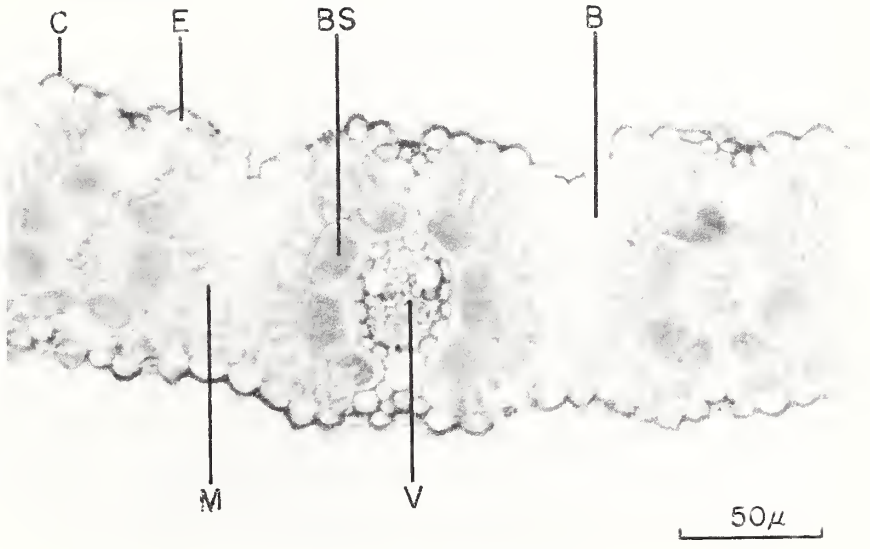

Fig. 5. Bermuda grass. Photomicrograph of unifacial leaf transection. Note bundle sheath and compact mesophyll.

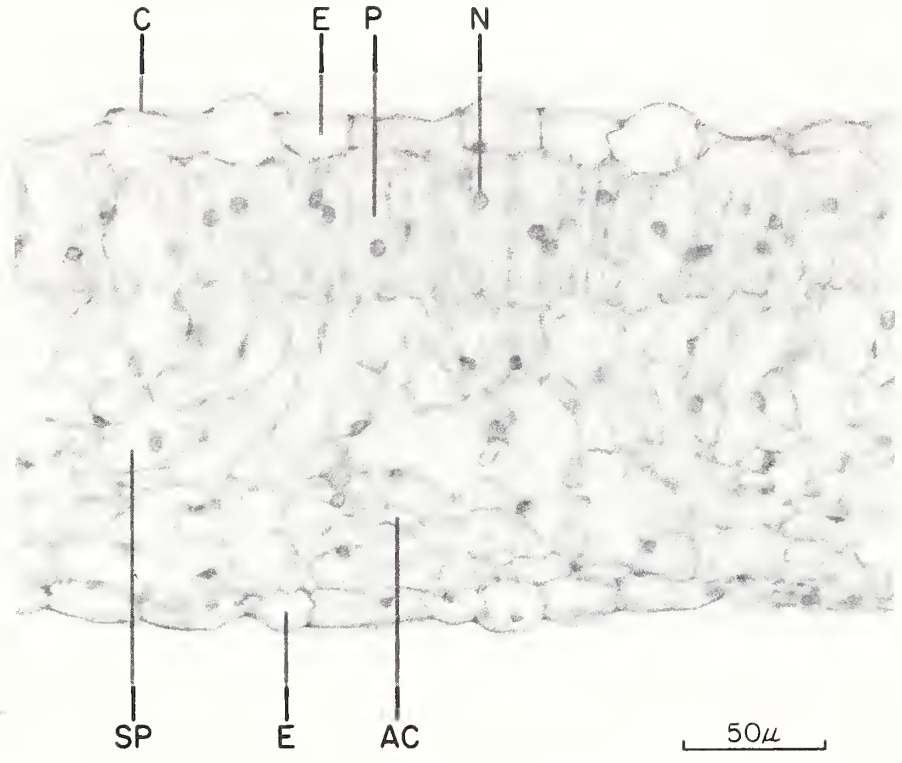

Fig. 6. Bougainvillea (variegated). Photomicrograph of dorsiventral leaf transection. Note prominent nuclei and the absence of chloroplasts.

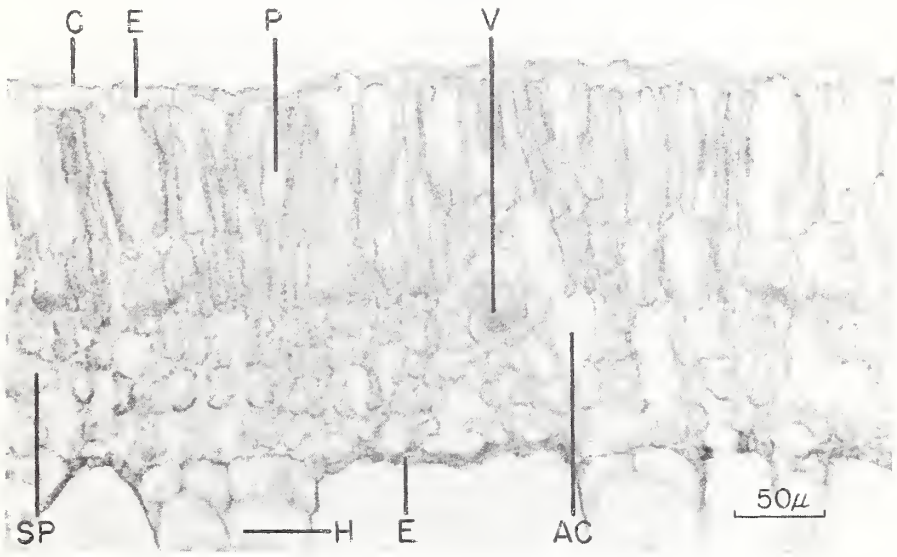

Fig. 7. Cantaloupe. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layers and hairs on the dorsal (lower) surface.

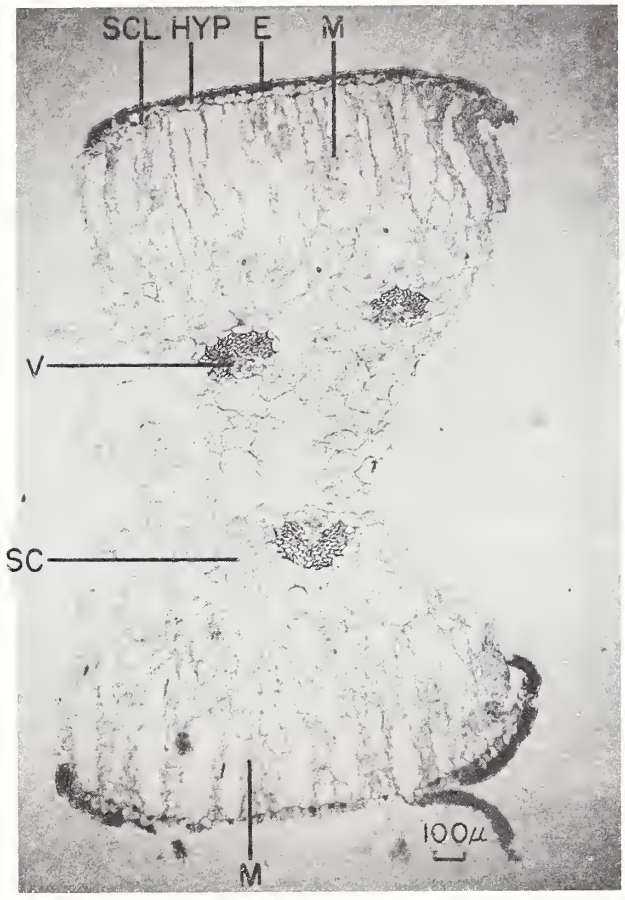

Fig. 8. Century plant. Photomicrograph of centric leaf transection.

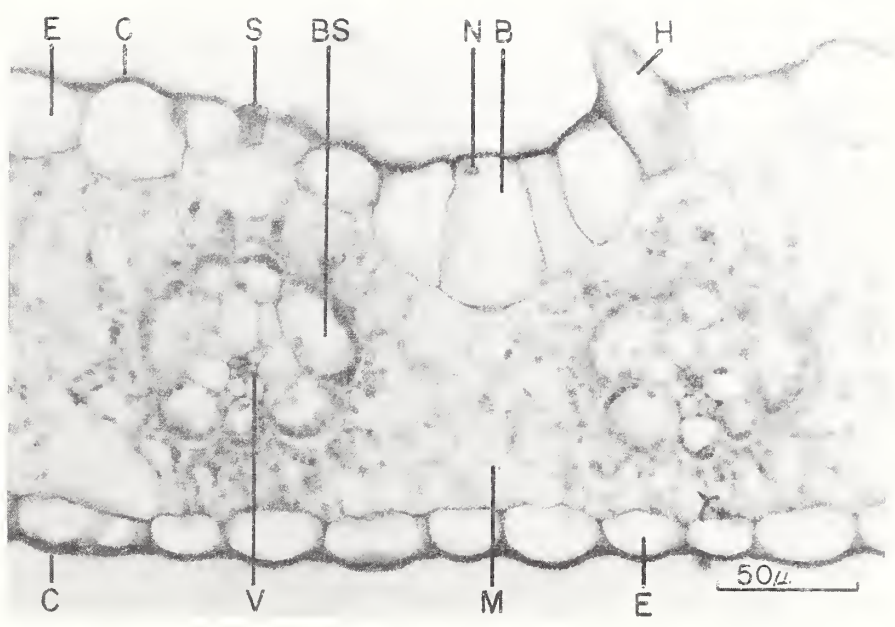

Fig. 9. Corn. Photomicrograph of unifacial leaf transection. Note compact mesophyll and bulliform cells.

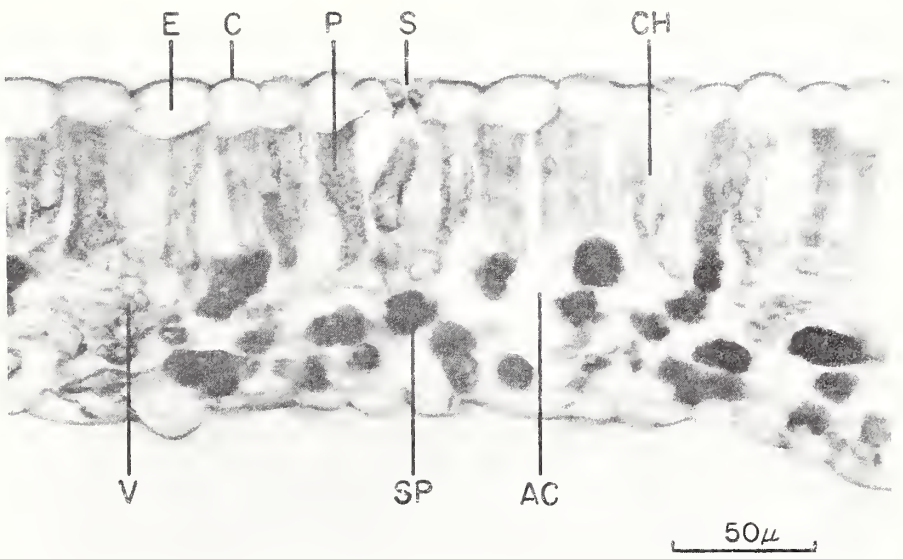

Fig. 10. Cotton. Photomicrograph of dorsiventral leaf transection. This sample was fixed in Navashin's solution, which caused the chloroplasts in the palisade cells to be clearly defined, and darkened some of the cells in the spongy parenchyma. Note the excellent stoma on the ventral (upper) surface.

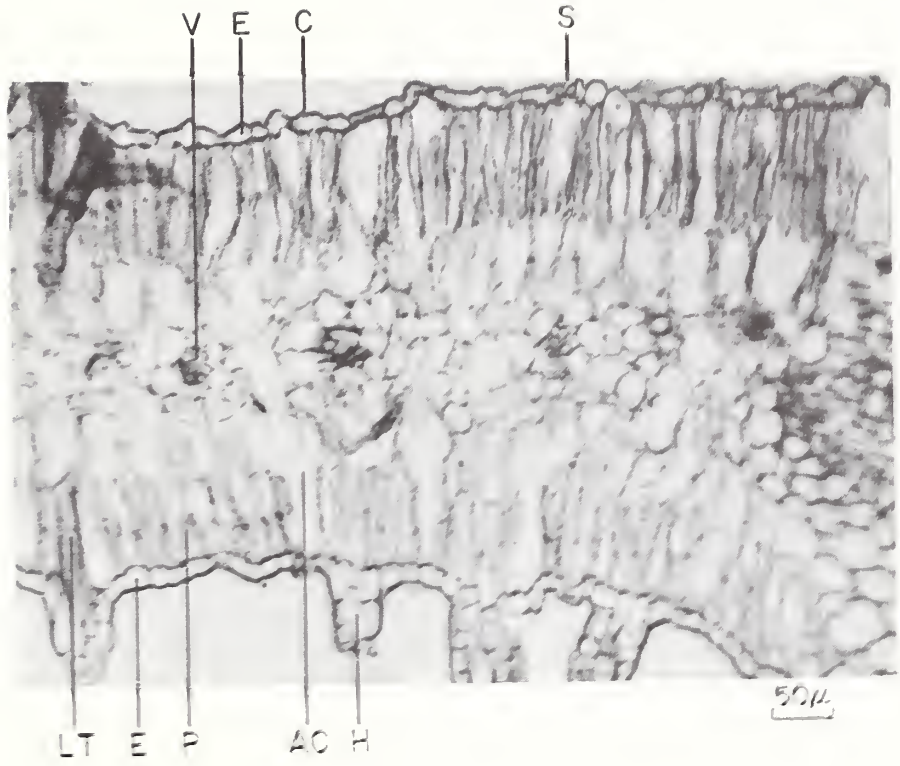

Fig. 11. Croton. Photomicrograph of isolateral leaf transection. Note hairs and laticiferous tubes containing latex.

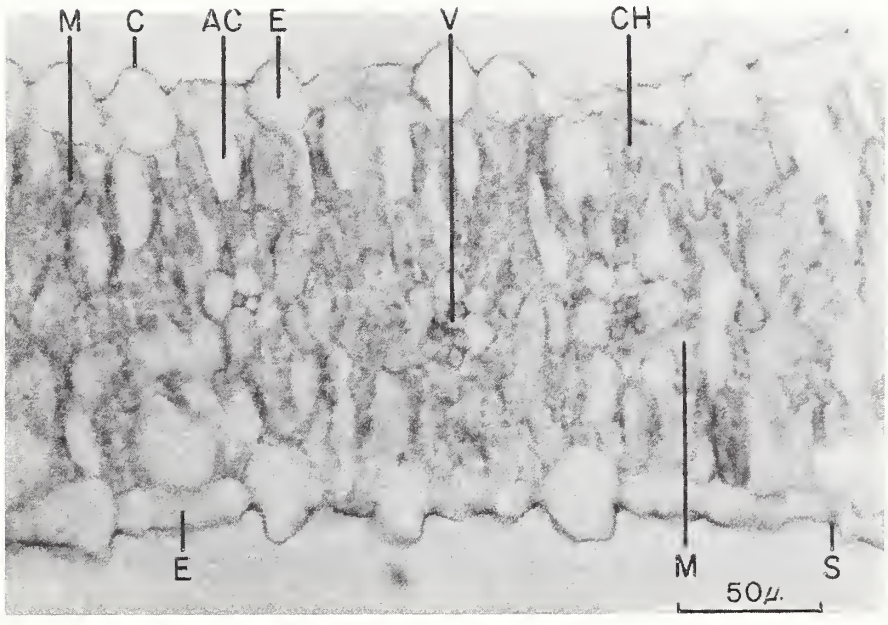

Fig. 12. Flax. Photomicrograph of centric leaf transection. Note mesophyll is poorly differentiated.

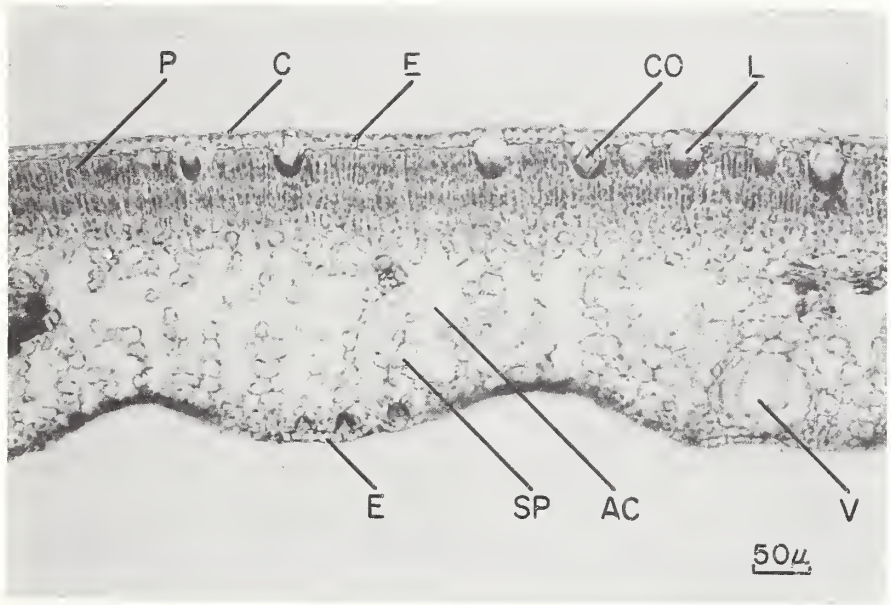

Fig. 13. Grapefruit. Photomicrograph of dorsiventral leaf transection. Note prominent cuticle, multiple palisade layer, lysigenous spaces, calcium oxalate crystals and abundant air cavities.

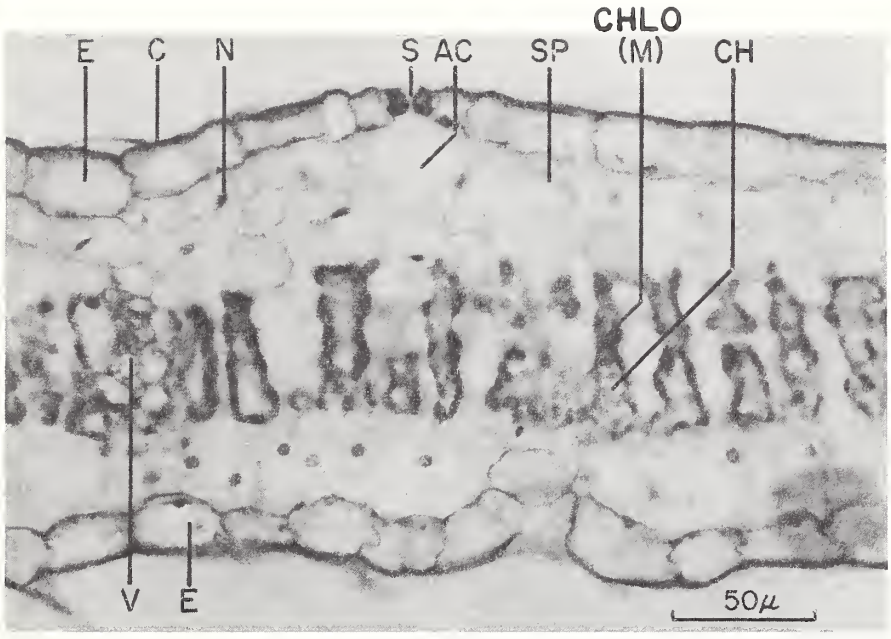

Fig. 14. Hibiscus. Photomicrograph of unifacial leaf transection. Note prominent nuclei in mesophyll, and centrally located chlorenchyma cells.

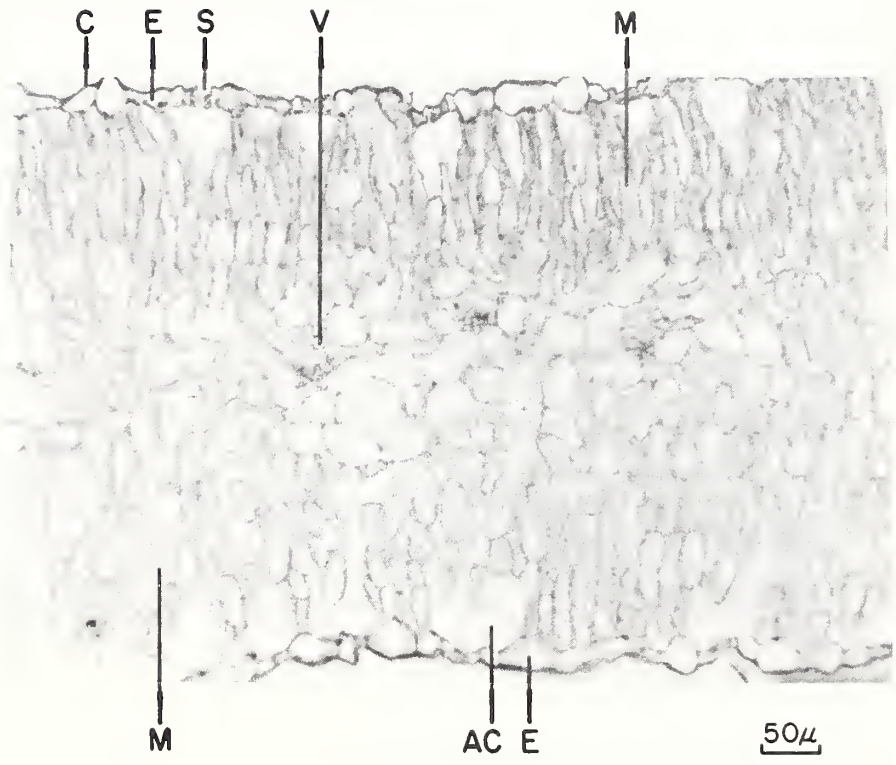

Fig. 15. Marine morning glory. Photomicrograph of centric leaf transection.

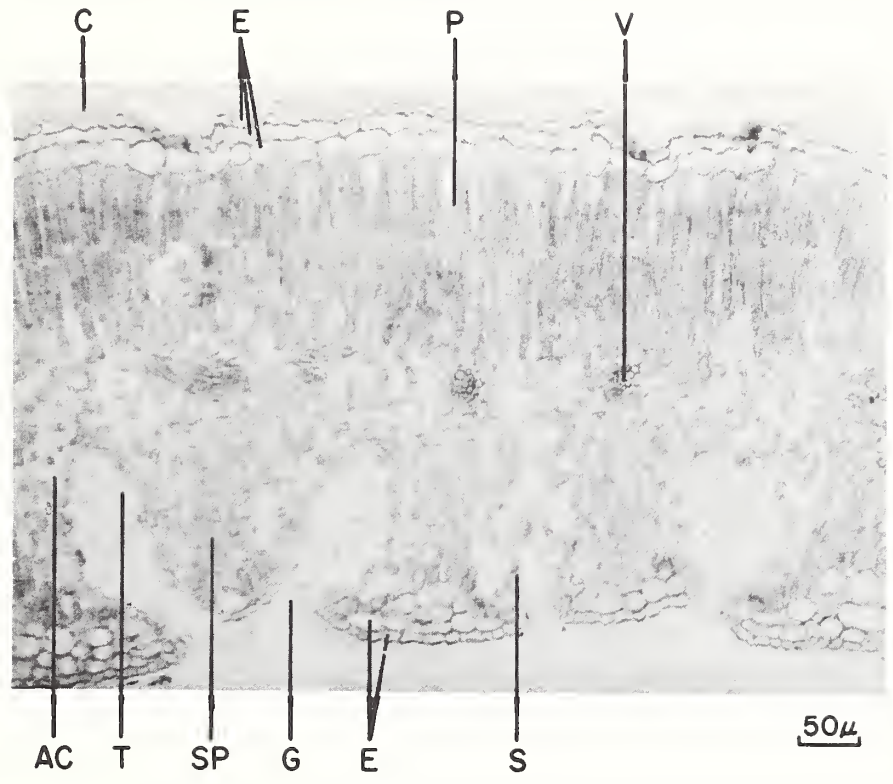

Fig. 16. Oleander. Photomicrograph of dorsiventral leaf transection. Note thickened cuticle, multiserate epidermis, multiple palisade layer; and stomatal crypts containing many stomata and trichomes. Also note that many cells contribute to the leaf thickness.

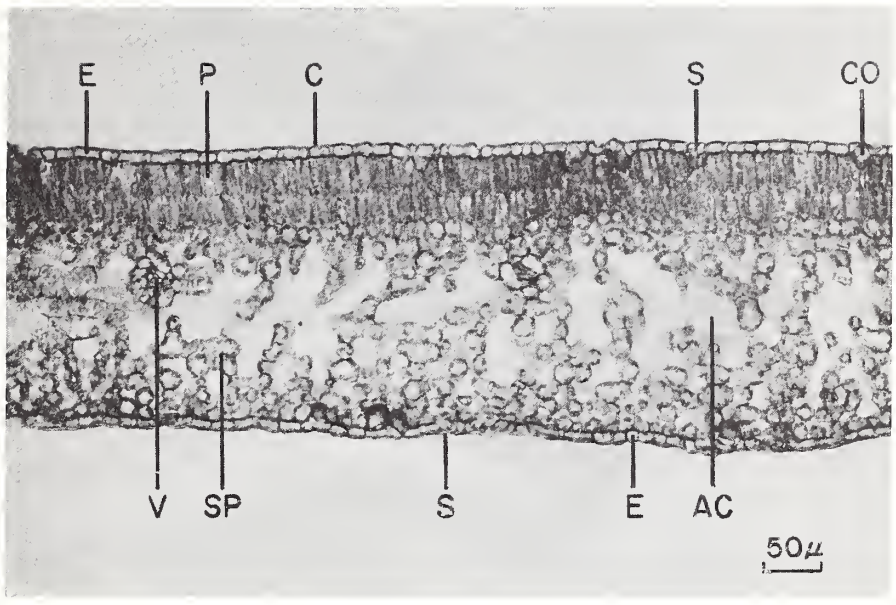

Fig. 17. Orange. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer and large amount of air space.

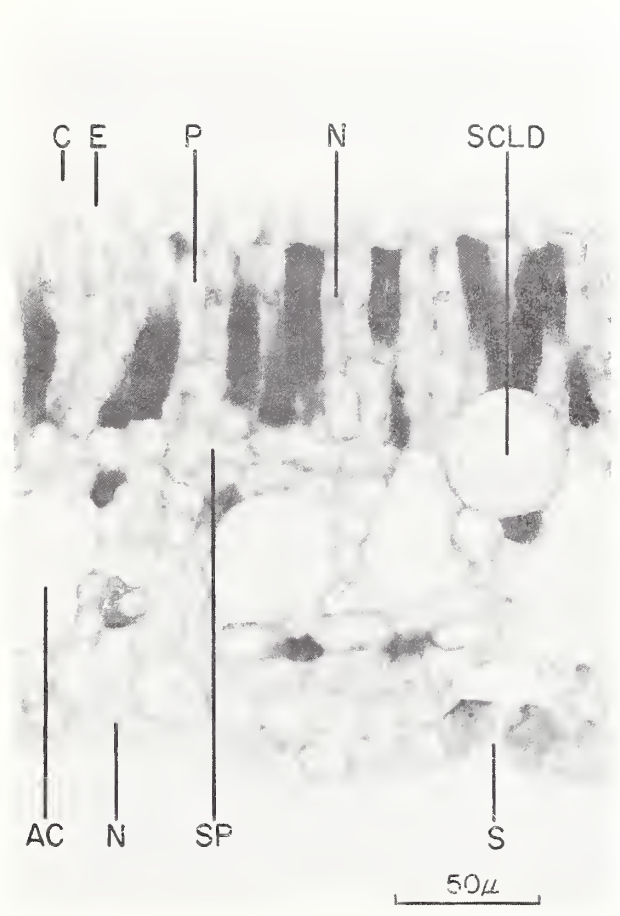

Fig. 18. Philodendron. Photomicrograph of dorsiventral leaf transection. Note large uniform air cavities and the sclereid.

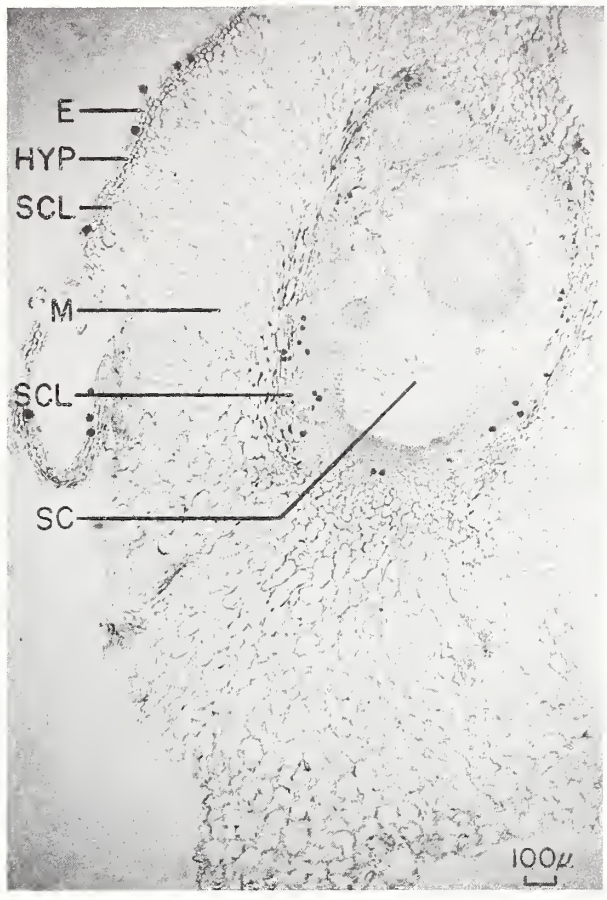

Fig. 19. Prickly pear. Photomicrograph of the transection of a portion of the leaf. Note largely undifferentiated mesophyll and prominent storage cells or area.

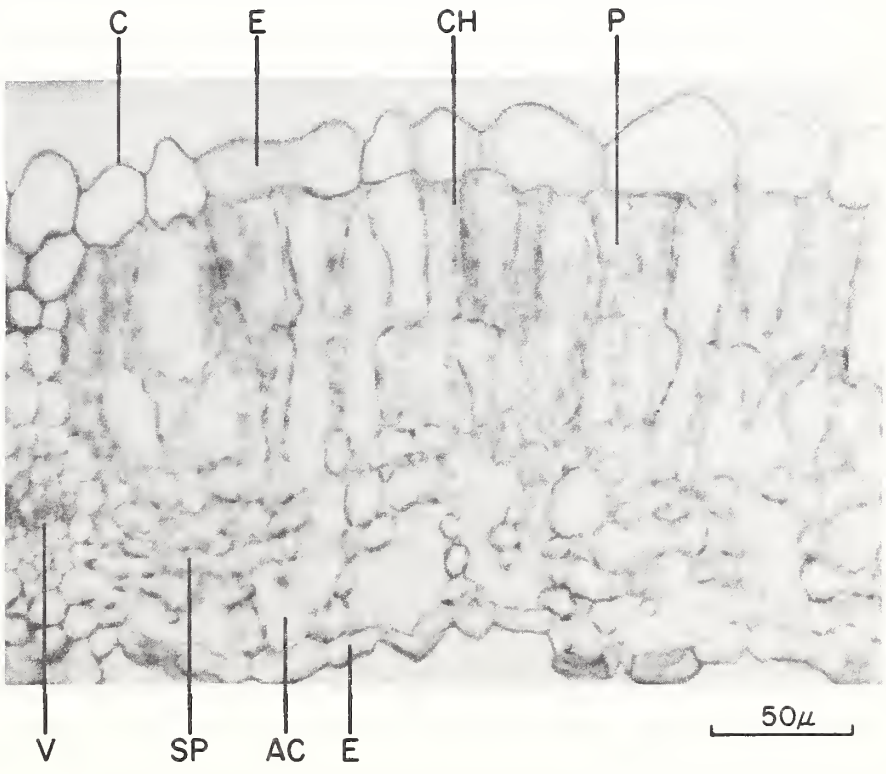

Fig. 20. Rice paper plant. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer and large epidermal cells on the ventral (upper) surface.

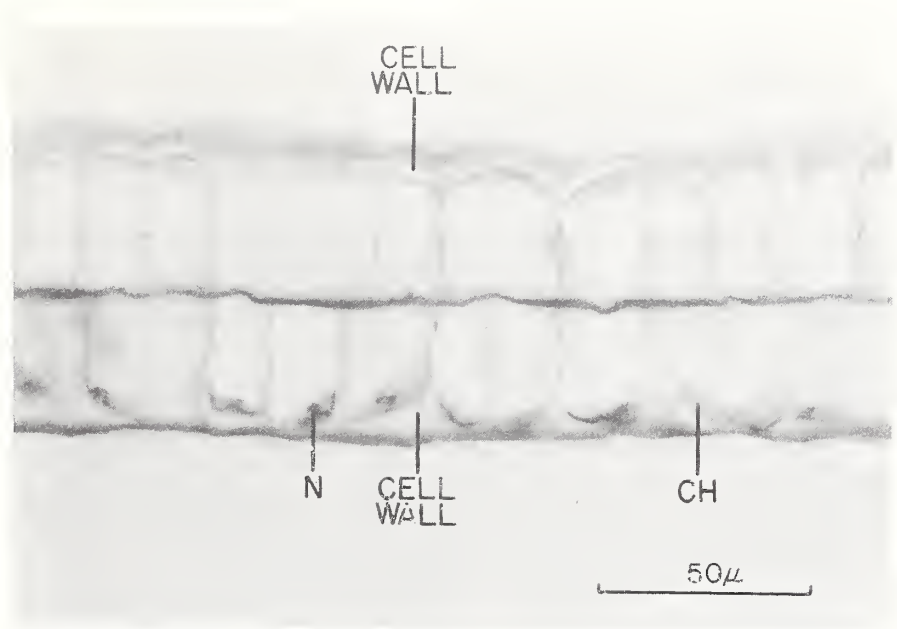

Fig. 21. Sea lettuce. Photomicrograph of thallus (not a true leaf) transection. Sea lettuce is a lower plant and cells may contain gametes. Note vegetative cells, two cells thick, with a nucleus and one cup-shaped chloroplast.

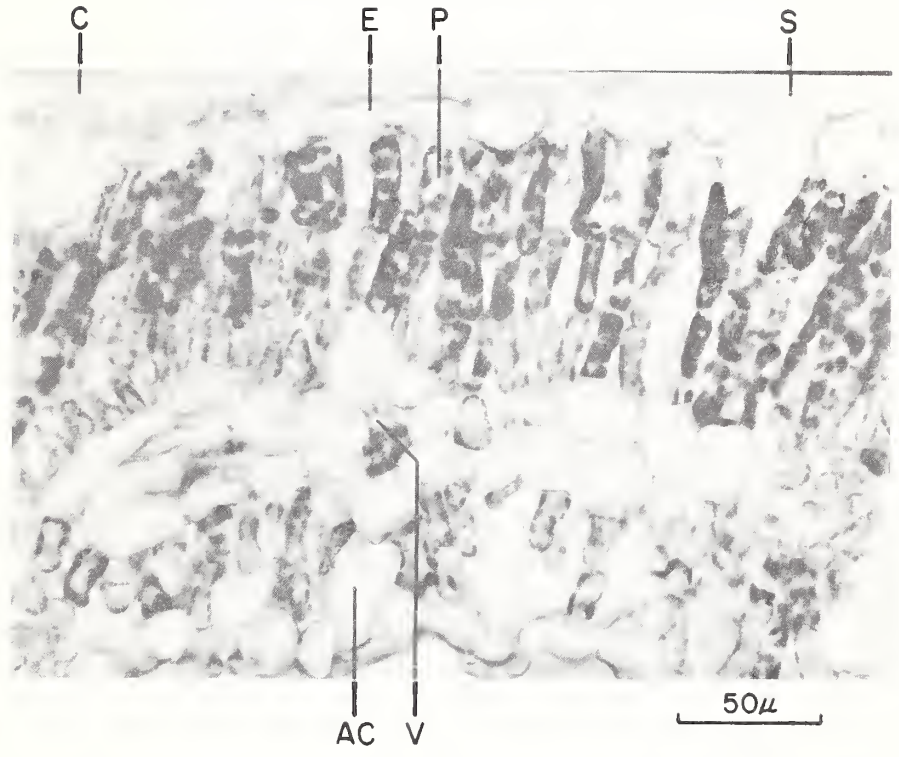

Fig. 22. Sea ox-eye daisy. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer. Darkening within cells occurs when leaves are removed from the plant.

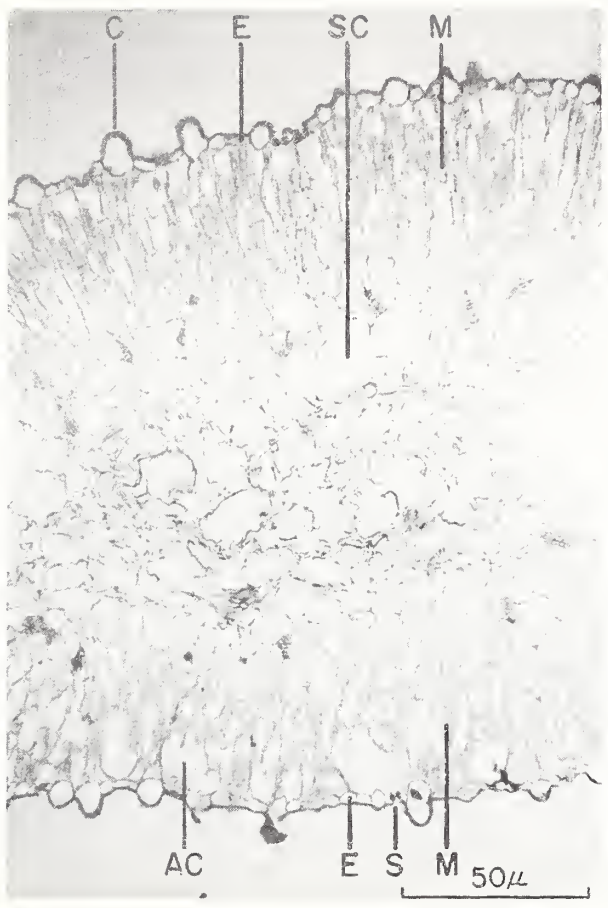

Fig. 23. Seaside purslane. Photomicrograph of leaf transections. Note largely undifferentiated mesophyll and prominent storage cells.

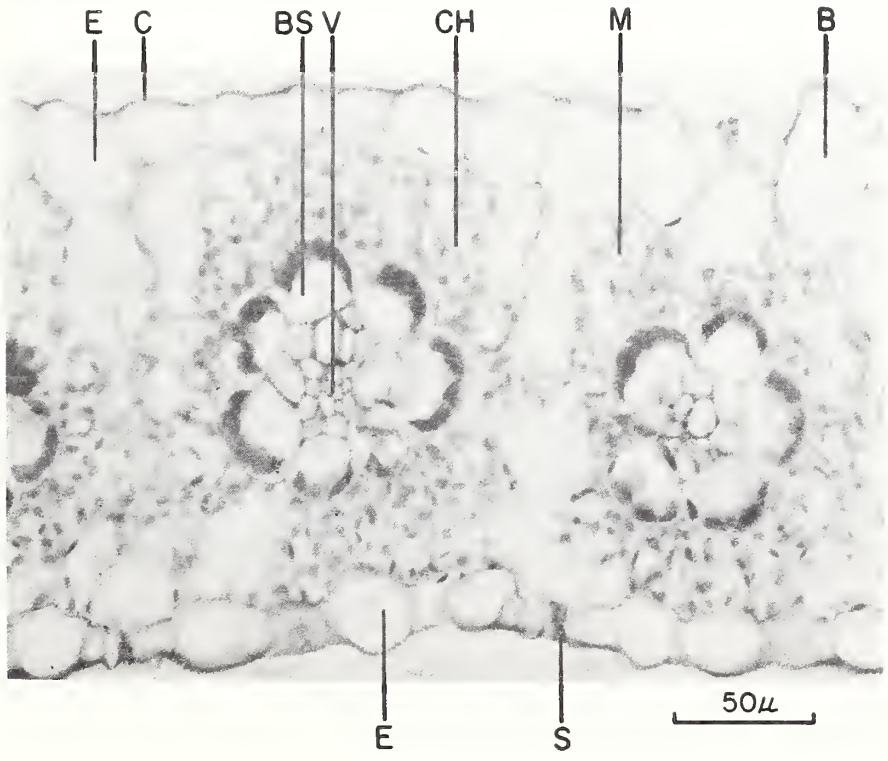

Fig. 24. Sorghum. Photomicrograph of unifacial leaf transection. Note bundle sheath.

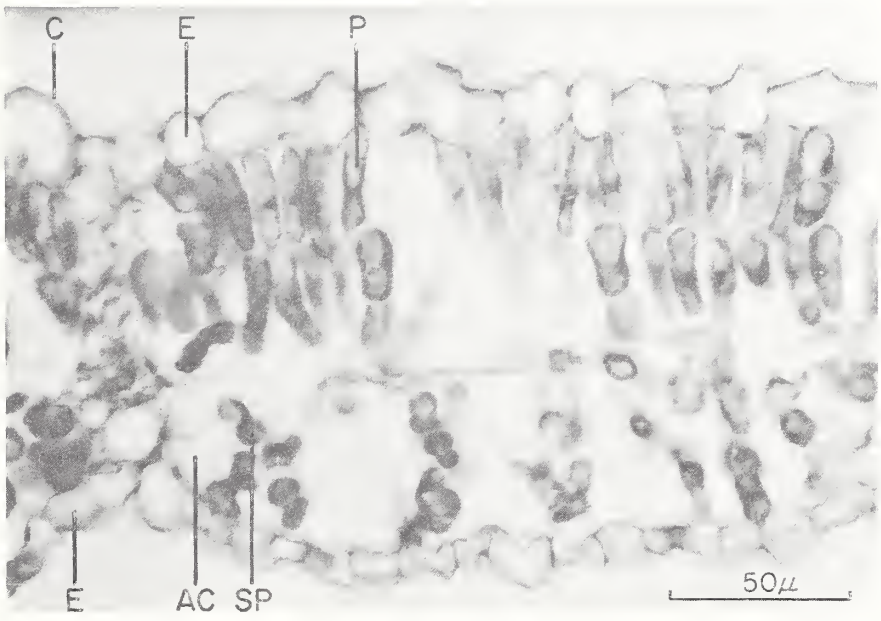

Fig. 25. Soybean. Photomicrograph of dorsiventral leaf transection. Note large intercellular spaces and darkened cells apparently typical of this genera.

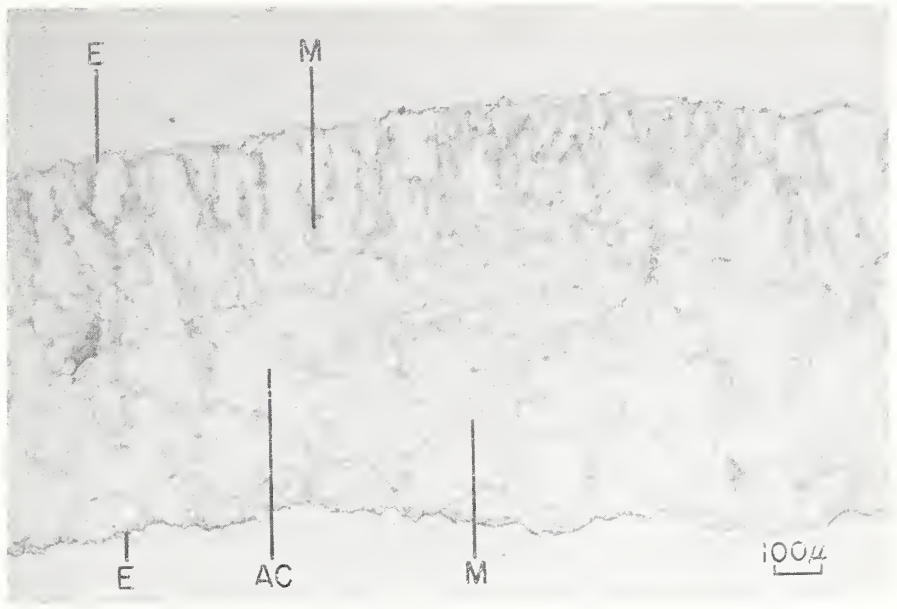

Fig. 26. Spinach. Photomicrograph of leaf transection. Note undifferentiated mesophyll and abundant air cavities. This leaf may have been stressed by saline soil conditions, or it may have greatly expanded during growth.

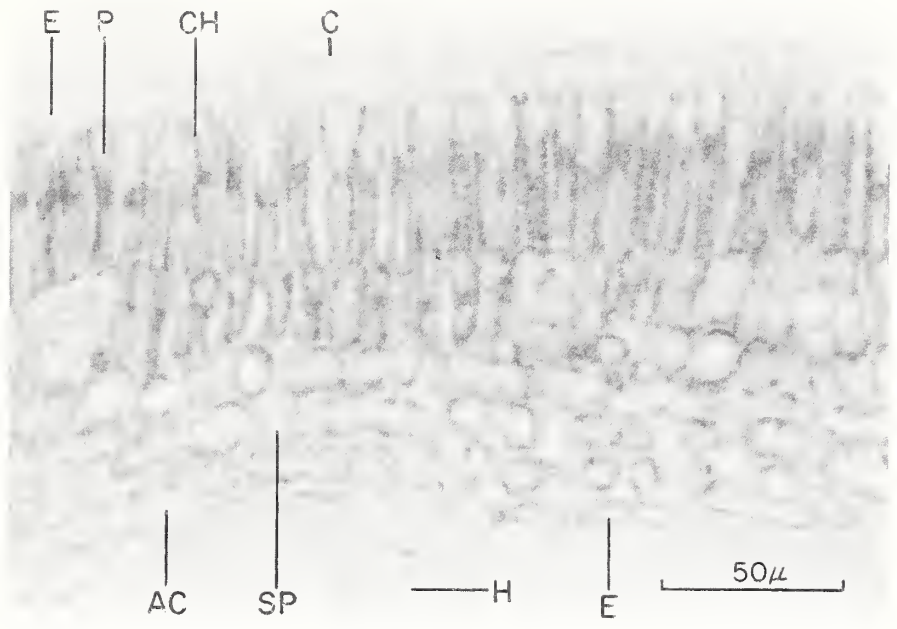

Fig. 27. Squash. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer and a portion of a multicellular hair.

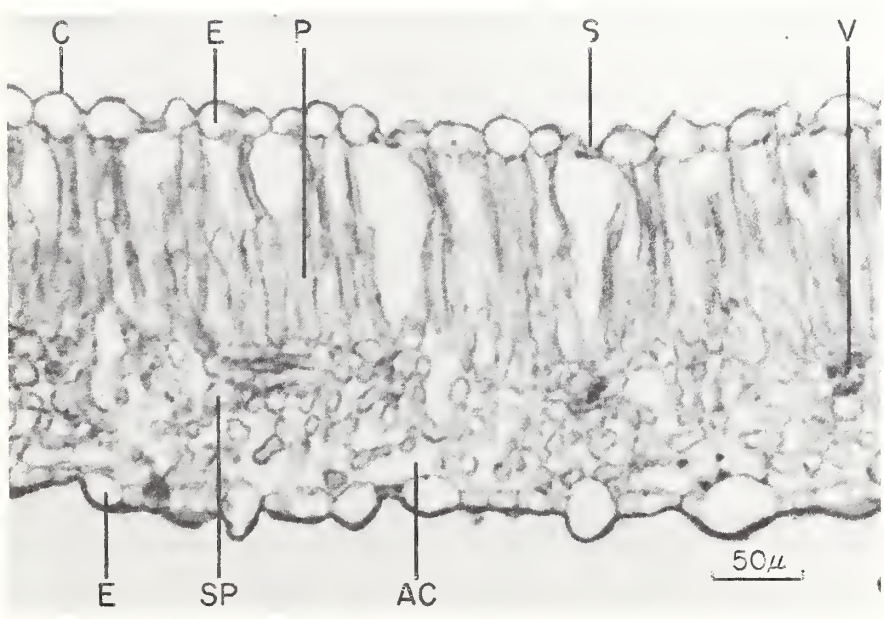

Fig. 28. Sweet clover. Photomicrograph of dorsiventral leaf transection. Note multiple palisade layer.

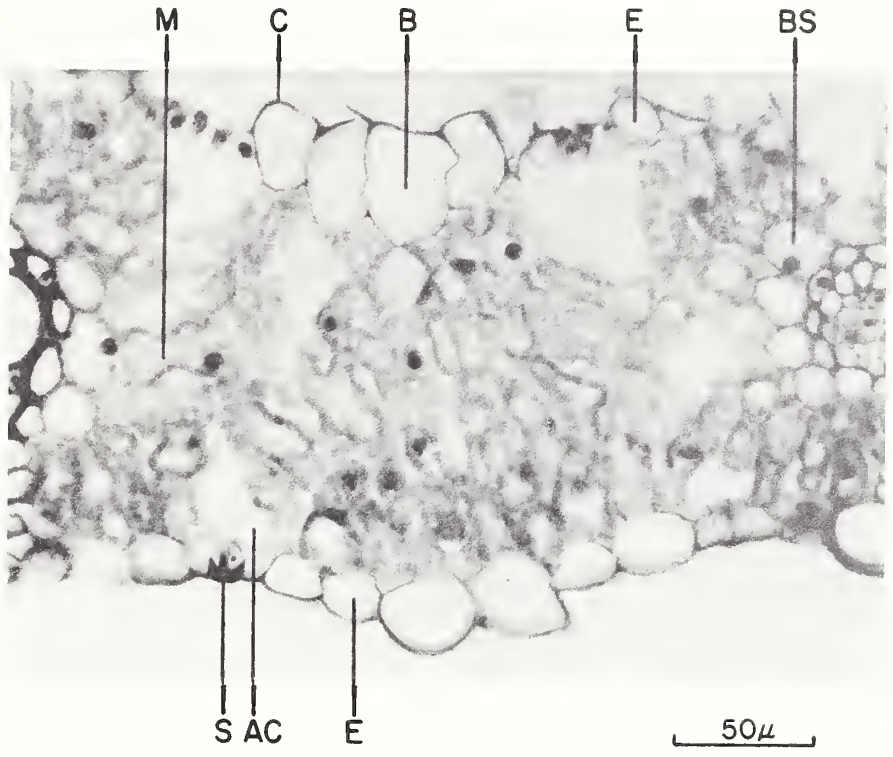

Fig. 29. Wheat. Photomicrograph of centric leaf transection. Note bulliform cells and the less compact mesophyll compared with corn and bermuda grass (Figs. 5 and 9).

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